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Upscaling a mixed-culture biofilm model in homogeneous porous media via multiscale asymptotics approach

Ahmed Fathi[1,2,3], Maria Rosaria Mattei[1],
Fernando G. Fermoso[2], Luigi Frunzo[1]

[1]Department of Mathematics and Applications "Renato Caccioppoli",
University of Naples Federico II, Naples, Italy
ahmedfathiibrahim.mohamed@unina.it
mariarosaria.mattei@unina.it
luigi.frunzo@unina.it

[2]Instituto de la Grasa,
Spanish National Research Council (CSIC), Seville, Spain
fgfermoso@ig.csic.es

[3]Faculty of Experimental Sciences,
University of Pablo de Olavide, Seville, Spain

A macroscopic model for biofilm growth in a homogeneous porous medium is constructed by upscaling the one-dimensional Wanner-Gujer multispecies biofilm model. The flow through the porous medium is assumed in a laminar and convection-dominated regime. The formal multiscale asymptotics method is applied to the mesoscale coupled system of elliptic-hyperbolic equations, which is a practical tool for determining the effective extent of various biofilm processes at the field scale. The mesoscopic biofilm model is composed mainly of a dual-species biofilm subject to growth and loss due to single substrate consumption and detachment, respectively.

The constructed model is a basic skeleton and the upscaling method is flexible to consider any number of bacteria species, and can be extended to various biofilm processes and kinetics (e.g., multiple substrates consumption, metals sorption and precipitation). The upscaling procedures end up with a stiff system of hyperbolic equations that are solved numerically. An original numerical code has been implemented on the MATLAB platform, based on the Uniformly accurate central scheme of order 2 (UCS2). To prove model consistency and highlight the main novelty of the work as compared to existing models, different simulation scenarios have been investigated by varying the following parameters: attachment velocity, detachment coefficient, and fluid flow rate.

The mixed-culture biofilm assumption was found to significantly affect the overall reactor performance, and the model outputs qualitatively agree with the physical expectations.

Keywords: biofilm, modelling, multiscale asymptotics, upscaling

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